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Heritability of life satisfaction in adults: a twin-family study

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ABSTRACT

Background. Subjective well-being (SWB) can be partitioned into the components life satisfaction and affect. Research on factors influencing these components of well-being has mainly focused on environmental characteristics. The aim of this study was to investigate the relative contribution of genes and environment to individual differences in life satisfaction in a large sample of Dutch twins and their singleton siblings.

Method. Life satisfaction of 5668 subjects registered with The Netherlands Twin Registry (NTR) was measured with a Dutch version of the self-reported Satisfaction with Life Scale. An extended twin design was used to obtain correlations in life satisfaction scores for monozygotic twins, dizygotic twins and sibling pairs and to estimate the contribution of genes and environment to the variation in life satisfaction.

Results. No differences between males and females were found in the mean level of life satisfaction. Broad-sense heritability was 38%. Non-additive genetic factors explained all or most of the genetic influences. The remaining 62% of the variance in life satisfaction could be attributed to unique environmental factors, both persistent and transitory, plus measurement error.

Conclusions. Individual differences in life satisfaction are determined in part by genetic factors that are largely or entirely non-additive in nature.

INTRODUCTION

Psychiatry and clinical psychology, almost by definition, have focused largely on negative affective states like anxiety, anger, and depression rather than on positive affective states like joy, vigour, happiness, or life satisfaction. This has led to a widespread definition of mental well-being as the absence of negative affect instead of the presence of positive affect (Korten & Henderson, 2000). The latter, however, is arguably more deserving of the predicate well-being. Although this focus on negative affect has given us powerful techniques for the reduction of human suffering, it may also have limited and biased our theories on mental health (Gillham & Seligman, 1999). According to Seligman & Csikszentmihalyi (2000) science and clinical practice that incorporate positive mood states will more optimally serve to increase the quality of life of many patients. They convincingly plead that we should not stop at attenuating the negative mood state of patients but aim further to build positive beliefs such as optimism, self-esteem, subjective well-being, courage, the capacity of pleasure and humour. These qualities will serve as a protective buffer to ensure future mental (Atienza *et al.* 2002) as well as somatic health (Kubzansky *et al.* 2001; Giltay *et al.* 2004).

To further expand our understanding of sources of variation in positive affective states, this paper focuses on subjective well-being (SWB). SWB is defined as the evaluative reaction of a person to his or her life and can be partitioned into the components *life satisfaction*

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(cognitive evaluation) and *affect* (emotional aspects of the construct, such as happiness) (Diener, 1984). Several studies have focused on the correlates of SWB, such as income (Veenhoven, 1991), and friendship and social activity (Harlow & Cantor, 1996). These factors correlate with well-being, but Lykken & Tellegen (1996) showed in an American twin sample that factors like socio-economic status, educational level, income, marital status, and religious commitment only explain about 3% of the variance in SWB. Costa *et al.* (1987) found similar results and concluded that stable characteristics (i.e. enduring dispositions in an individual) are more useful in predicting SWB than life circumstances, such as changes in work and residence. This finding is in agreement with results from a study by Brickman *et al.* (1978). They confirmed that SWB is strongly influenced by enduring characteristics of the individual by stating that even paralysed accident victims and lottery winners differ little in happiness level. A recent study in an American sample of 909 employed women also showed that positive affect and enjoyment are strongly influenced by aspects of temperament and character (Kahneman *et al.* 2004).

Currently, there are four studies addressing the question to what extent genetic factors contribute to variation in SWB. Lykken & Tellegen (1996) used the Well-Being (WB) scale of the Multidimensional Personality Questionnaire to assess happiness in 2310 adult twins (age span from 20 to 30 years), resulting in a heritability estimate of around 50%. The correlation for MZ twins was substantial, whereas the correlation for DZ twins was negligible, suggesting that the genetic effects are non-additive (i.e. comprise interactions between genes). Similar results were found in an earlier study using the same measurement instrument (Tellegen *et al.* 1988). The heritability in this study was estimated at 48% and results showed that non-additive effects played an important role in explaining individual differences in well-being. In both studies the unique environment explained the remaining variance. In a sample of 5140 young Norwegian adult twins (aged 18–25 years) genetic factors also explained about 50% of the variance in SWB and unique environmental factors explained the remaining part (Røysamb *et al.* 2002). Contrary to Lykken & Tellegen (1996) and Tellegen *et al.* (1988), Røysamb *et al.* found slightly different estimates for men (46%) and women (54%). All genetic effects were explained by additive genetic effects and non-additive genetic effects could be omitted from the model. This is in keeping with results from a study using a larger sample of 6576 Norwegian twins aged 18–31 years (Røysamb *et al.* 2003). Interestingly, an observation study using 128 zoo chimpanzees found similar results for SWB (Weiss *et al.* 2002), resulting in substantial additive genetic effects.

To our knowledge, not much attention has been paid to the heritability estimates of affect and life satisfaction separately, although research has suggested that these two components of SWB show some degree of independence and, therefore, should be measured and studied individually (Lucas *et al.* 1996). Therefore, in this paper we investigate the relative contribution of genes and environment to variation in life satisfaction in a large sample of Dutch twins and their non-twin siblings. Adding siblings to the classical twin design increases the statistical power to detect sources of variance due to additive and non-additive genetic influences, and common environment (Posthuma & Boomsma, 2000). Furthermore, this approach provides an optimal design to address the question whether levels of life satisfaction differ between twins and non-twins and, therefore, whether the results from twin studies on the genetics of life satisfaction may be generalized to the general population.

METHOD

Subjects

This study is part of an ongoing study on health and lifestyle in twin families registered with The Netherlands Twin Registry (NTR). Since 1991 every 2–3 years twins and their families have received a survey sent by mail containing a number of personality inventories, and items about health, regular exercise, alcohol consumption and smoking behaviour (Boomsma *et al.* 2002). In October 2002, questionnaires were sent to twins, their spouses, parents, and siblings. In March 2003, non-respondents received the questionnaire for the second time. Twins and family members who registered after March 2003 received the questionnaire once.

Table 1. *Number of families with a specific family constitution*

No. of siblings …	0	1		2			3		4
Sex of siblings …		♂	♀	♂♂	♀♀	♂♀	♂♂♀	♂♀♀	♂♂♀♀
MZM families									
2 twins	139	39	32	5	7	7	3	2	1
1 twin	143	10	17	2	1	2	2	—	—
DZM families									
2 twins	59	12	21	1	—	—	2	3	—
1 twin	115	12	12	1	5	2	2	—	—
MZF families									
2 twins	409	53	99	11	14	15	2	4	4
1 twin	272	30	44	—	3	1	—	—	—
DZF families									
2 twins	182	31	41	7	9	10	—	2	—
1 twin	206	16	3	24	5	4	—	—	—
DOS families									
2 twins	167	36	49	3	10	6	—	4	1
1 twin	294	30	51	1	6	8	—	1	—
No twins	—	64	149	2	11	12	2	3	2

MZM, monozygotic males; DZM, dizygotic males; MZF, monozygotic females; DZF, dizygotic females; DOS, dizygotic opposite-sex pairs.

In this paper we analyse the twin and sibling data from this survey. Questionnaires were sent to 14 162 twins/triplets and 3606 siblings from 7261 families. At the end of the data collection, a total of 4521 twins (response rate 32%) and 1455 siblings (response rate 40%) from 3153 families had returned a questionnaire. Data from non-biological siblings ($n=30$) were discarded. If information on sex ($n=2$), age ($n=5$), zygosity ($n=73$) or life satisfaction ($n=170$) was missing, we did not include the participants in the analyses. Finally, we used a maximum number of two additional male sibs and two additional female sibs per twin family, thereby excluding 28 siblings. After removing these participants, the final dataset consisted of 4329 twins and 1339 siblings ($N=5668$ participants) with an average age of 33·2 years (S.D. = 11·3, range 14·1–88·3 years). About 75% of the subjects were between 20 and 40 years of age. Table 1 gives the twin/sibling composition of the participating families.

Zygosity of 919 same-sex twins was determined on the basis of DNA typing. For the remaining 2467 same-sex twins, zygosity was based on questions about physical similarity and confusion in identifying the twins by family members, friends, and strangers. For the opposite-sex twin pairs, zygosity is known (DZ) based on their sex. In our sample, agreement between zygosity based on questionnaire data and zygosity based on DNA results was 98%. Grouped according to zygosity and sex, the twin sample consists of 647 monozygotic male twins (MZM), 345 dizygotic male twins (DZM), 1572 monozygotic female twins (MZF), 822 dizygotic female twins (DZF), and 943 dizygotic opposite-sex twins (DOS). The sibling sample is composed of 535 males and 804 females.

Measurement

Life satisfaction refers to the cognitive component of SWB and can be defined as a global assessment of a person's quality of life according to a person's own subjective judgement (Shin & Johnson, 1978). This means that the degree of life satisfaction is based on a unique set of criteria which each individual sets for himself (Diener *et al*. 1985). The Satisfaction With Life Scale (SWLS) was used to assess global life satisfaction (Diener, 2005). The SWLS contains five items on life satisfaction, such as 'In most ways my life is close to my ideal'. Participants respond on a scale ranging from 1 (strongly disagree) to 7 (strongly agree).

The scale was translated into Dutch by Arrindell *et al*. (1991). Both the original and the Dutch version of the SWLS have demonstrated good psychometric properties, including high internal consistency and reliability, and the scale is suitable for use with different age groups (Diener *et al*. 1985; Arrindell *et al*. 1991; Pavot & Diener, 1993). A total score was calculated by summing the scores of each individual item resulting in a possible range of scores from 5 (low satisfaction) to 35 (high satisfaction). In our sample, Cronbach's α was 0·86.

Analytical procedure

Quantitative analyses of life satisfaction were carried out in several steps. First, to determine the extent to which MZ twin pairs are more similar than DZ pairs or sibling pairs, correlation coefficients were calculated using the software package Mx (Neale *et al*. 2003). Comparing the MZ twin-pair correlations with the DZ twin-pair and sibling-pair correlations provides a first estimate of the sources of variation in individual differences in life satisfaction. MZ pairs are genetically identical, whereas DZ

and sibling pairs on average share 50% of their segregating genes. Therefore, additive genetic effects (A) on life satisfaction are suggested if the intra-pair correlation in MZ twins is substantially larger than the correlation in DZ twins/singleton sibling pairs. These effects reflect the additive effects of alleles of multiple genes. If the DZ correlation is higher than half the MZ correlation, this indicates that common environmental effects (C) contribute to individual differences in life satisfaction and these effects refer to all environmental factors that contribute to twin similarity. If the opposite is true (i.e. the DZ correlation is lower than half the MZ correlation), this suggests that non-additive genetic effects explain individual variation in life satisfaction (Neale & Cardon, 1992; Plomin *et al.* 2000). Non-additive genetic effects comprise interactions between two alleles at a locus (dominance) or interactions between genes at different loci (epistasis). Common environmental and non-additive genetic sources of variance are confounded in the classical twin study (i.e. including only MZ twin pairs and DZ twin pairs/sib pairs. Therefore, they cannot be estimated at the same time. Finally, because MZ twins have identical common environment and identical genes, an intra-pair correlation different from unity indicates unique environmental effects on life satisfaction (including measurement error).

Structural equation modelling was used to fit different models to the data. First, we fitted a saturated model to estimate the correlations between twin pairs, twin-sibling pairs, and sibling-sibling pairs. In model-fitting procedures, the saturated model is used as a starting-point for the comparison of different, nested models. The fit and parsimony of the various nested models are judged using likelihood ratio tests in which the negative log-likelihood (-2 LL) of the nested model is compared with -2 LL of the saturated model. Subtracting the two -2 LLs from each other yields a statistic that is asymptotically distributed as χ^2 with degrees of freedom (df) equal to the difference in the number of parameters in the two models. According to the principle of parsimony, models with fewer parameters are preferred if they do not give a significant deterioration of the fit ($p > 0{\cdot}05$).

After estimating the correlations for the different groups, we tested the assumptions of homogeneity of means and variances for MZ twins, DZ twins, and singletons by constraining parameters to be equal or fixing parameters to be zero in the saturated model. We tested whether age and sex influenced individual differences in life satisfaction by retaining these two variables as covariates in model-fitting procedures.

Finally, we tested for heterogeneity of correlations between men and women and between DZ twin and sibling pairs. The latter comparison tests whether there is a specific twin environment. A lower correlation in sibling pairs compared to the correlation in DZ pairs indicates that there may be a specific twin environment influencing individual differences in life satisfaction.

The most parsimonious model was retained to estimate the relative contribution of genetic and environmental influences to individual differences in life satisfaction. The pattern of twin and sibling correlations indicated an ADE model (and not ACE), therefore, the first model decomposes the variances into additive genetic influences (A), non-additive genetic influences (D), and unique environmental influences (E) and tested the significance of D.

RESULTS

Mean score for life satisfaction was 27·83 and did not differ between males and females. A small decrease in life satisfaction was found with increasing age ($\beta = -0{\cdot}03$). This is in keeping with findings from earlier research indicating that there are few age effects and only very small or no differences between men and women in life satisfaction (Arrindell *et al.* 1991; Pavot *et al.* 1991). Means and variances of MZ and DZ twins and singleton siblings did not differ significantly from each other, indicating that there are no twin–singleton differences in life satisfaction. In the saturated model we tested whether there were male–female differences in total variance. The variance in males (26·83) was smaller than in females (29·70).

Table 2 displays the correlations for all zygosity groups and for the sibling pairs. For both males and females, MZ correlations are larger than DZ correlations, indicating that genetic factors play an important role in explaining individual differences in life satisfaction. The MZ correlations for both men and women are more

Table 2. *Maximum-likelihood estimates of twin and sibling correlations and the 95% CIs*

	r	95% CI	*n**
Monozygotic male twins	0·31	0·19–0·43	235
Dizygotic male twins	−0·01	−0·18–0·17	98
Monozygotic female twins	0·40	0·33–0·46	611
Dizygotic female twins	0·10	0·03–0·22	282
Dizygotic opposite-sex twins	0·11	0·00–0·22	276
Brothers	0·18	0·00–0·49	55
Sisters	0·09	−0·12–0·29	94
Brother–sister	0·01	0·00–0·17	165
Male twin–brother	0·05	0·00–0·17	281
Female twin–sister	0·10	0·02–0·18	689
Male twin–sister/female twin–brother	0·11	0·03–0·19	801
Female twin–brother	0·11	0·03–0·19	468
All monozygotic twins†	0·38	0·33–0·44	846
All first degree relatives†	0·09	0·05–0·14	4055

r, correlation; CI, confidence interval; *n*, number of complete pairs.

* Correlations are based on complete and incomplete pairs.

† After constraining these correlations to be equal.

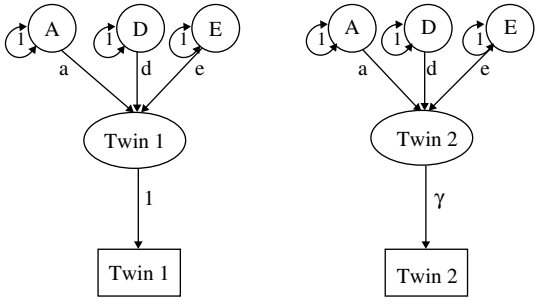

FIG. 1. ADE scalar model. The figure represents a dizygotic opposite-sex pair where the first-born twin is a male and the second-born twin is a female. Rectangles depict measured phenotypes and circles surround latent variables. A (additive genetic effects), D (non-additive genetic effects) and E (non-shared environmental effects) represent the sources of variance. The letter γ denotes the scalar parameter and accounts for the difference in variance between men and women. Path coefficients are represented by a, d and e.

than twice as large as the correlations for the DZ twins and sibling pairs, suggesting that non-additive genetic effects contribute to individual differences in life satisfaction. The twin correlations for MZM and MZF were the same. All correlations in dizygotic twins were also equal (i.e. rDZM = rDZF = rDOS). Finally, all sibling correlations were equal to the DZ correlations, showing that DZ twins do not resemble each other more than other first-degree siblings (i.e. there is no specific twin environment).

To account for the heterogeneity in the variances of males and females, a scalar model was used in the variance decomposition models (Fig. 1). In this model the total variance of the females is specified as a scalar times the variance of the males. The relative contributions of the variance components are equal for males and females, because there were no sex differences in the twin or sibling correlations. As expected, dropping the scalar from the model gave a significant deterioration of the fit ($p = 0{\cdot}01$).

Table 3. *Univariate model fitting results for twins and siblings: goodness of fit* ($\Delta\chi^2$) *for saturated and genetic models*

Model	*v.*	−2 LL	df	$\Delta\chi^2$	Δdf	*p* value
1. Saturated model		34931·46	5645			
2. ADE model	**1**	**34947·13**	**5662**	**15·67**	**17**	**0·55**
3. AE model	2	34962·35	5663	15·22	1	0·00
4. E model	2	35094·57	5664	132·22	1	0·00

A, additive genetic effects; D, non-additive genetic effects; E, unique environmental effects; *v.*, *versus* and indicates with which model the submodel is compared to; −2 LL, −2 log-likelihood; df, degrees of freedom.

The most parsimonious solution appears in boldface type.

The results of genetic model fitting are summarized in Table 3. Compared to the saturated model, the ADE model gives a good fit to the data in this large dataset. Excluding non-additive (D) genetic influences from the model (AE model) resulted in a significant worsening of the fit ($p < 0{\cdot}05$), and dropping both the additive and dominance genetic variance components was also not allowed ($p < 0{\cdot}05$). Thus, the ADE model without sex differences in heritability is the best-fitting model. Non-additive genetic factors explained 38% (95% CI 20–44) of the variance. The point estimate of the additive genetic effects was 0% (95% CI 0–16). The remaining 62% of the variance was attributed to unique environmental factors (including measurement error) (95% CI 0·56–0·67).

DISCUSSION

SWB can be partitioned into the components life satisfaction and affect. Research on factors influencing individual differences in these components of well-being has mainly focused on environmental characteristics. A few genetic studies mainly targeted the component of SWB as a whole. The aim of this study was to examine the relative contribution of genes to variation in the cognitive component of SWB (i.e. life satisfaction). In a large sample of Dutch twins

and their siblings, genetic model fitting showed a significant contribution of genetic factors (38%) to life satisfaction. Environmental factors unique to the individual, rather than the environment shared by family members, explained the largest part of the variance in life satisfaction (62%).

To our knowledge, the sources of variance in the cognitive component (i.e. life satisfaction) of SWB have been studied only once before in a sample of elderly subjects from the Swedish Adoption/Twin Study of Aging (Harris *et al.* 1992). In twins with an average age of 51 years, 32% of variation in life satisfaction could be attributed to genetic factors, which compares well to our finding in young adult to middle-aged twins and siblings. In the oldest age twin group (average age 72 years) genetic effects on life satisfaction were substantially larger (52%). We extended these findings by including SWLS data from twins as well as from additional siblings present in the twin family. This provides an optimal design to test whether there are specific twin effects. Based on our results we conclude that the estimates of genetic and environmental contribution to variation in life satisfaction can be generalized to the general Dutch population.

A second advantage of using the extended twin design is that the statistical power to discriminate between additive genetic effects and common environmental and non-additive effects increases. We found that the genes underlying life satisfaction appear to act in a non-additive manner. This corresponds to the findings of Lykken & Tellegen (1996) on the affective component of well-being, who also found high MZ correlations and much lower DZ correlations. A further study by Tellegen *et al.* (1988) reported a heritability of 48% for SWB, and again non-additive genetic effects had to be included in the model. Taken together, these findings suggest that the genetic effect on well-being and life satisfaction is characterized by non-additive genetic variation, which can consist of dominance variation or epistatic variation or both.

The genetic architecture of well-being is relative unique compared to findings in other studies investigating typical personality traits like neuroticism. For example, in a large twin study on a sample of 45 850 Australian and American subjects individual differences were explained by large additive genetic effects and only very small non-additive effects were found (Lake *et al.* 2000). Dominance variance of a trait refers to the variance due to the interaction effect of the two alleles that define the genotype at a locus. Dominance is distinct from the interaction that may occur between genotypes at separate loci (i.e. epistasis). The confidence interval for the additive (95% CI 0·00–0·16) and non-additive (95% CI 0·20–0·44) variance components are large, indicating that the estimate of the additive component could be anywhere between 0% and 16%, whereas the non-additive variation lies between 20% and 44%. Such large fluctuations in estimates were discussed by Eaves (1972) who used computer simulation to show that estimates of non-additive genetic influences and additive genetic influences are negatively correlated. The estimate of the broad heritability (i.e the heritability due to additive and non-additive genetic influences) is stable, but large fluctuations in the estimates of the two components occur. Information from many different genetic relationships (e.g. twins, half siblings, parent–offspring) are needed to reliably separate additive genetic influences from non-additive genetic influences in non-experimental studies.

The mean level of SWLS score is relatively high compared to the findings in other countries. As information on life satisfaction was accumulated by mailed surveys, selective non-response to mailed surveys may have introduced bias if refusal to participate was not distributed randomly, being higher in those scoring low on the SWLS. However, the high level of SWLS is in agreement with results from a study comparing life satisfaction of people from 31 nations that showed that Dutch people tend to have higher average levels of life satisfaction compared to citizens of other countries (Diener & Diener, 1995). To investigate potential bias further, we exploited the genetic relatedness in our sample. Vink *et al.* (2004) proposed the use of data from respondents as a proxy for the data from their non-responding family members to estimate the non-response bias in a twin-family study. Results showed that scores of members from incomplete twin pairs tended to be more unfavourable (for example higher scores on anxious depression and neuroticism) than the scores from complete twin pairs. In our sample, no differences in life satisfaction between MZ

twins from complete pairs *versus* incomplete MZ pairs were found ($p = 0{\cdot}56$) and DZ twins from complete pairs also did not significantly differ in life satisfaction from incomplete DZ twins ($p = 0{\cdot}89$).

We did not find effects of environmental factors that are shared by members of a sibship, for example socio-economic class of the parents. Generally the absence of an impact of socio-economic factors on life satisfaction is in good agreement with a recent study by Kahneman *et al*. (2004) who found that positive affect and enjoyment were strongly influenced by aspects of temperament and momentary environmental influences. General circumstances like income and education only had a small influence on the enjoyment of a regular day.

Two studies showed that the instrument used here (SWLS) can reliably detect changes over time, such as the increase or decrease of life satisfaction after positive or negative life events (Vitaliano *et al*. 1991; Suh *et al*. 1996). As discussed by Pavot & Diener (1993), these studies suggested that life satisfaction has a long-term component due to stable life circumstances (e.g. due to personality), a moderate-term component (e.g. due to recent life events or current work load), and a short-term state component (e.g. due to current mood). Our results are in agreement with such a model, and suggest that the individual differences in the long-term component of life satisfaction may be caused by genetic factors, whereas the moderate-term and short-term state component may be caused by environmental factors specific to the subject.

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DECLARATION OF INTEREST

None.

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